Sketch of Experiments in Sound, Heat, Light, Electricity, and Magnetism.

GOODEVE AND GUTHRIE.

NOTE.

The following sketch of experiments in the subjects Sound, Heat, Light, Electricity, and Magnetism, is intended to assist Teachers in conducting classes in the respective subjects. It is to be looked on in the light of an outline only. All the experiments not marked should be shown to pupils in the "advanced" stage, and as many as possible to those in the "elementary" stage of the Science syllabus. A few experiments marked A. require special and more expensive apparatus, and their introduction must be left to the discretion and material resources of the teacher.

Preserving this outline the Teacher should vary and multiply the experiments to the utmost of his power.

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SKETCH OF EXPERIMENTS.

SOUND.

A body in a state of vibration produces sound. *Production of sound.*
A glass goblet set in vibration in contact with pith balls.
A tuning fork set in vibration in contact with pith balls.
A large tuning fork struck and waved exhibits its vibrations.

Alarum or musical box under the receiver of the air pump. *An elastic medium is necessary.*
The end of a long wooden rod scratched by a pin.
One prong of a tuning fork is armed with a cork cone which is plunged in water contained in a tube one end of which is fastened to a sounding board.

Propagation of sound.

All bodies are compressible.

Bending of solids. Elasticity of air in syringe. Boyle's Law.

Propagation of force through a row of solitaire balls.

A tin funnel covered with a membrane is inserted into a tube filled with smoke, and struck.

Nature of sound wave or undulation.

Baden Powell's apparatus for transverse vibrations.

A thin vulcanized india-rubber tube 30 feet long, stretched (best vertically), shows transverse pulse and its reflexion, also the simultaneous existence of several pulses.

A thin tube as above, loaded with sand, and marked with tape, shows the passage of longitudinal vibrations, and their reflexion.

The same experiments with increased tension.

Baden Powell's apparatus employed to show that separate particles are in different phases.

Reflexion of sound.

Speaking tubes.

Ticking of watch heard through a long tube.

The same assisted by reflector behind the watch.

Refraction of sound.

Refraction of sound through a collodion balloon filled with carbonic acid.

N.B.—*The reflexion and refraction of sound may be made manifest by a sensitive flame.*

Imperfect elasticity and mechanical dispersion.

A hand bell ceases to be sonorous when heated over a Bunsen burner.

A glass goblet or funnel ceases to be sonorous when it contains an effervescing liquid.

Notes.

Dotted line formed on slate by pencil when a note is produced.

The same with brass tubing scraped with a knife.

Trevelyan's rocker.

Electric syren.

Toothed wheels on whirling table with card.

Perforated disk of cardboard on whirling table produces notes when air is blown upon the holes.

Syren.

Preliminary experiments to determine pitch of fork and organ pipe by coincidence with note of syren (without beats).

Rate of sound in air.

A whistle connected with an inflated india-rubber bladder is fastened to the whirling table. The note is graver during approach than during recession.

Transverse vibrations of elastic rod.

Vary length of very long rod swinging transversely in vice, and obtain law of vibration according to length.

Wheatstone's kaleidophone and figures (may be reflected and focussed on screen).

Effect of loading the rod.

A.—Lissajou's figures.

1 : 1, 1 : 2, 2 : 3, 3 : 4, &c.

Graphic analysis of vibrations exhibited by moving lamp-blackened surfaces across points fastened to selected forks.

Transverse vibrations of strings.

Vary length of stretched wire
„ tension „ „
„ thickness „ „
„ material „ „
and deduce law of vibration.

Examine actual motion of a vibrating string by means of a bright bead fastened to it.

Nodes.

Nodes on long elastic rod held in the hand.

Nodes in struck bar vibrating transversely.

Musical glasses and sonorous bars.

Harmonics on tuning fork when the bow is drawn near the root, exhibited by strewn sand.

Chladni's figures on round and square plates, exhibited by sand and lycopodium.

Nodes on bell, exhibited by suspended pith balls and water in inverted bell-glass.

Multiple nodes in stretched indian-rubber tubing, one end being held in the hand.

Nodes formed in elastic ring on compressing and extending opposite sides.

Silk cord stretched across the mouth of a bell jar or bell exhibits nodes.

Silk cord stretched between vibrating forks shows nodes.

A.—Large fork (not sonorous) worked by electric " make and break," and fastened to a stretched silk cord, developes nodes.

Production of nodes by damping various points of a stretched steel wire. Test for nodes by riders.

Further inquiry into wave motion.

Experiments with spiral steel wire stretched spring, such as :—

(1.) Vibration when upper end is fastened and lower end is loaded. Compare with elastic rod fastened at one end.

(2.) Fasten at both ends and vibrate longitudinally and transversely.

(3.) Fasten as (2.). Damp the centre and obtain the same nodes for transverse and longitudinal vibrations.

(4.) Increase number of nodes.

Longitudinal vibrations in a brass bar clamped in its centre exhibited upon a suspended ivory ball touching its end.

Longitudinal vibrations in a bar of wood.

Longitudinal vibrations in a rod of glass, exhibited by the creeping of a paper ring.

Compound longitudinal nodes on a strip of glass or metal.

Longitudinal vibration of a column of air, (a) closed tubes.

Air nodes in wide glass tube with moveable piston set up by longitudinal vibrations of an inserted brass bar (lycopodium).

Compare above with single resonant cylinder.

Resonance of closed cylindrical tubes with selected forks.

Closed tubes of lengths 1, 3, 5, &c., resound to the same fork, say C.

Closed tubes of lengths 2, 6, 10, &c., resound to lower octave of C.

(b) open tubes.

Open tube of length l vibrates to fork C.

„	„	$2l$	„	„	C and C′.
„	„	$3l$	„	„	C not C′.
„	„	$4l$	„	„	C and C′, &c., &c.

N.B.—*For closed tubes, glass cylinders tuned with water may be used. Numerous telescopic tubes of cardboard both closed and open should be constructed.*

Compare notes of open and closed tubes of equal length.

Examine nodes and segments in an organ pipe with a paper tray.

A.—Examine nodes in organ pipe by extinguishing gas jets in side chamber for fundamental note and octave.

Selection of vibrations by resonant column.

Cardboard disks are loaded and hung up by double wires of various lengths. Another card giving rythmical puffs of air sets one or other of the hung cards in oscillation.

A jet of hydrogen, when lighted beneath a glass tube, gives a resonant pop.

A rustling flame is converted into a sonorous one by a selected resonant tube.

Examine noise of embouchure with and without organ pipe.

Blow across open end of closed tube or jar with contracted neck, or phial.

Sonorous goblet with resonant tube.

Metal bell with resonant box, closed and open.

Series of forks with resonant cylinders.

Use of sounding boxes with forks.

Alteration of law of resonance by spreading cavities.

Vowel spheres and forks.

Jews' harp.

Human voice reed pipes and other wind instruments.

India-rubber model of larynx.

Reed, with and without pipe.

Trumpet stop-pipe.

Trumpet.

Willis's "mama tube."

Compare closed pipe with a longitudinally vibrating spring with one end fixed.

Rate of travel of sound.

Length of closed pipe is one quarter of the wave length. Know or determine the number of vibrations of a fork resounding to a closed jar. Measure depth of jar, and so deduce the velocity of sound in air.

Make the same determination by means of an open tube; the length of an open tube being one half the wave length.

Show how the closed tube must be altered in length when filled with hydrogen or carbonic acid in order to resound to a given fork.

Bars of brass, glass, and wood of equal length, when in longitudinal vibration, require resonant air columns of different lengths: hence deduce sound rate in these solids.

Compare notes by transverse and longitudinal vibrations in brass and iron wires.

Communication of vibrations.

Sympathetic vibrations of forks in air.

Sympathy of tuned strings on monochord exhibited by riders on segments and nodes.

Sand on drum with organ pipe.

A bar held vertically is fastened to two blackened brass circular disks, upon which sand is strewn; the bar is rubbed with resined leather. The arrangement of the sand exhibits the transformation of longitudinal into transverse vibrations.

The above apparatus is held above a drum strewn with sand.

The sounding board is attached to a stretched string or fork.

The musical box is placed in the double felt case. A wooden rod with sounding board is introduced.

Sympathetic vibrations in a piano, violin, &c.

Interference beats.

Concord of forks.

Beats of forks on boxes and above a resonant cylinder.

Loading of forks.

Beats with organ pipes.

Beats between organ pipe and syren.

Beats between tuning fork and syren.

Determination of the number per second of the vibrations of several tuning forks by means of the elimination of beats.

A.—Beats by double syren.

Dissonant forks.

Lissajou's forks, parallel and vertical, to show interference by sinuosities on screen by consonant, harmonic, and dissonant forks.

Turn fork over resonant jar to detect lines of extinction at corners.

Interference in organ pipes illustrated by membranes, gas jets, and vibrating mirror.

Singing and sensitive flames.

Various sensitive flames affected by different vowels, and by hissing, rustling, &c.

Analyze singing flame in tube by means of a mirror.

Set up vibration in flame by an organ pipe or tuning fork.

Sympathy between two pipes when tuned by a moveable casing.

Approach caused by vibration.

Balanced card disk attracted by tuning fork.

Cotton wool attracted by tuning fork.

Balanced card attracted by disks on rod in longitudinal vibration.

Hydrogen in collodion balloon repelled by tuning fork.

HEAT.

Simple experiments in expansion of solids, liquids, and gases.

Lengthen a stretched platinum wire by heating it by a galvanic current.

Fergusson's pyrometer, used with various metals through a fixed range.

Water, alcohol, mercury, oil, &c., completely filling equal flasks (2 oz.), provided with narrow tubes, are heated.

Air in a flask is expanded by heat, and a portion is expelled through a tube and collected over water.

A wide-mouthed balloon is held over a gas flame till it rises.

An air-tight, somewhat shrivelled bladder, becomes tense on heating.

The air thermometer and differential air thermometer constructed and explained.

Inequality and equality of expansion.

A compound band of copper and iron rivetted shows by its curvature when heated the superior expansion of copper.

A.—Complete galvanic circuit by the expansion of brass before the same is effected by iron.

Compound metal ribbons, as of silver and platinum curl when heated.

Equal flasks of water, alcohol, oil, mercury, &c., full and furnished with narrow tubes, are equally heated. The liquids are found to expand unequally.

Equal flasks of air, nitrogen, oxygen, hydrogen, carbonic acid, &c., are equally heated by hot water, and the volumes of the gases expelled through narrow tubes and collected over mercury are the same.

Break cast-iron pin by the contraction of a cooling rod of iron. **Force of expansion and contraction.**

Rupert's drops.

Break flasks of water quite full by expansion.

Make thermometers (alcohol and mercury) and determine fixed points. **Thermometers.**

Daniells' pyrometer.

A.—Make and use a model of Siemen's pyrometer.

Bring a cylinder of ice-cold water into a warm room, and test the temperature above and below. **Maximum density of water.**

Allow a full flask of ice-cold water with a narrow tube and inserted thermometer to become warm.

Wooden balls are stuck with soft wax at equal intervals along two bars of iron and copper placed end to end, heated at the place of contact. The superior conductivity of the copper causes the balls on it to fall off soonest. **Conduction. Solids.**

Equally long cylinders of ivory, glass, clay, and various woods and metals are placed on flat top of air thermometer, and receive heat from above.

The same arrangement, substituting thermo-pile for air thermometer.

Apparent passage of cold by the above arrangements.

Boil water at top of test-tube held in the hand. **Liquids.**

Boil water in test-tube over loaded ice.

Surround bulb of air thermometer with a cup containing water whose level is above the bulb, and pour hot water on the cold.

Examine conductivity of mercury, water, oil, oil of turpentine, tetrachloride of carbon, &c., by Guthrie's liquid conductivity cones.

The hand, covered with asbestos, supports a red-hot ball. **Gases.**

Quenching of red-hot spiral of platinum by hydrogen.

Put out flame of candle by thick copper coil of wire. **Illustrations of conduction.**

Burn gas above wire gauze.

Davy's lamp.

Test sensation of cold on plunging the hand into various liquids of the same temperature, as mercury, water, oil, &c.

Compound cylinder of brass and wood with serpentine division to scorch paper.

Melt a spherical leaden bullet in paper envelope.

Bran or shreds of paper in round-bottomed flask heated over gas flame, show convection currents. **Convection.**

Streaks of water produced by descending currents of cold water from ice.

Streaks of ascending currents in water from heated platinum spiral (heated by galvanic current).

Same in flask of water when near boiling.

Show by two flasks and connecting tubing hot water circulation.

Ventilation exhibited by candle burning in a bell jar carrying a chimney divided by a diaphragm. The air current tested by smoke.

Heat platinum wire by current and show the ascending air on screen (fore-shorten).

Project on screen the hot currents from a candle and gas jet.

Project on screen the currents from a hot poker, &c.

Capacity for heat.

Compare the capacities of three glass cylinders of different diameters for water. Show how the withdrawal or addition of equal quantities of water affects the level.

Cylindrical slabs of metals of equal weight heated to the same temperature, melt different quantities of ice or wax. (Iron, zinc, lead, copper, bismuth, &c.)

Balls of the above metals of equal size heated in oil bath to 130° C. penetrate a cake of wax to different degrees.

A ball or cube of copper heated to different degrees heats a given weight of cold water. (Siemens' copper cube pyrometer.)

Unit of heat.

Burn gunpowder mixed with sand in a copper vessel under water, and show that nearly the same amount of heat is absorbed in heating two weights of water one degree as in heating one weight two degrees.

Specific heat.

Equal weights of various hot metals are plunged into cold water of given weight, and the specific heats of the metals deduced.

Known weights of various hot metals are treated as above.

Known weights of cold metals are plunged into known weights of hot water to obtain confirmatory results.

Model of calorimeter for solids.

Mix 1 lb. of ice cold mercury with 1 lb. of water at 100° C.

Mix 1 lb. of ice cold water with 1 lb. of mercury at 100° C.

Perform the same experiments substituting oil of turpentine for mercury.

Vary the quantities, temperature, and nature of the sub stances, and deduce their specific heats.

Weigh a penny and a half-crown, boil them in water, place them in a cavity of ice covered with an ice slab, and weigh by means of blotting paper the quantities of ice they melt, and so deduce their specific heats.

Latent heat.

Determine the latent heat of water by pouring a pound of boiling water on a pound of dry powdered ice, and determining the temperature of the mixture.

Vary the temperature of the water and the quantity of the ice and water.

Weigh a cake of wax or paraffin just beginning to melt in hot water, melt a part of it by a known weight of boiling water, and determine its latent heat from the resulting temperature.

Pass low pressure steam into a known weight of ice cold water till the latter is at 100°: from the increase in weight of the water, deduce the latent heat of the steam.

Substitute boiling oil of turpentine for boiling water in the above, and deduce latent heat of vapour of oil of turpentine.

Vary the quantity, temperature, and nature both of the condensing substances and the vapours to determine the latent heats of the latter.

Relation of heat to change of state.

Surround bulbs of differential air-thermometer with cups of water, and dissolve various salts in one cup.

A.—Place shallow platinum crucible lid with water on thermo-pile, and dissolve various salts in the water. Show thermo current by galvanometer.

Water, alcohol, ether, &c. placed on bulb of air thermometer or differential air thermometer absorb heat by their evaporation.

Cold produced by effervescence of mixed liquids.

Gases liquifying evolve heat, *e.g.*, ammonia and hydrochloric acid in water.

Liquids solidifying evolve heat, *e.g.*, a super-saturated solution of sulphate of soda poured upon the bulb of an air thermometer.

The same upon a protected thermo-pile.

Slake lime and hydrate anhydrous sulphate of copper, and so evolve heat by solidifying water.

Fuse various solids by heating them.
Solidify „ liquids „ cooling „
Vapourize „ liquids „ heating „
Condense „ vapours „ cooling „

A.—Various experiments with solid carbonic acid, *e.g.*, mix with ether, freeze mercury, therewith freeze water, freeze sulphurous acid, &c.

Illustrations of thermal effect of change of state.

Freezing mixtures.

Ice produced by evaporation under air pump.

Ice formed in cryophorus.

A.—Ammonia freezing machine.

Still or Liebig's condenser.

Heat absorbed by expansion.

Air compressed and cooled in copper vessel impinges on bulb of air thermometer.

A.—Air as above impinges on thermo-pile (*compare also "mechanical heat"*).

Ebullition.

Difference of boiling points of various liquids, *e.g.*, water, alcohol, turpentine, &c.

Rectify alcohol.

Variation of boiling point with pressure.

Flask of boiling water corked and cooled, recommences to boil.

Warm water boils under the air pump, also warm alcohol.

Boil either under air pump.

Tension of vapours.

Introduce a series of liquids into a series of barometers, *e.g.*, water, alcohol, ether, bisulphide of carbon, &c., and so measure their vapour tension.

Depress the above into deep copper or glass well to show condensation.

Surround the above by a glass cylinder of water of various temperatures.

Experiments with Marcet's boiler.

Crush a tin vessel by atmospheric pressure against steam vacuum.

Syphon gauge for steam tension.

Regelation.

Adhesion of blocks of ice to one another and to flannel.

Cut a block of ice by a loaded wire.

Press ice through a wide meshed wire gauze.

Compress snow into ice.

Spheroidal state.

Water dropped into red hot silver basin.

Water drops held by pipette on outside of hot platinum cup. The non-contact proved by break in circuit with galvanometer.

Force a cork out of a copper flask (silvered internally) by the burst of steam after spheroidal state.

Steam, a true gas.

Heat a steam cloud and examine its shadow.

Show the transparency of steam in the constricted water hammer.

Radiant heat.

(1.) Radiant heat reflected:

A red hot ball throws heat upon a bright tin plate which reflects it on to an air thermometer or pile.

A candle flame at one end of a long bright tin tube and an air thermometer or thermo-pile at the other.

(2.) Radiant heat absorbed:

Use of air thermometer with blackened bulb.

(3.) Radiant heat transmitted:

Copper ball, thin sheet of glass and air thermometer or thermo-pile.

Place boiling water in two similar saucepans, one externally blackened, the other bright. Examine after half an hour the temperatures by differential thermometer. Radiation from various surfaces.

Experiments with Leslie's cubes. Compare radiation on air thermometer from lamp black, bright metal, scratched metal, isinglass, and glass sides of cubes.

A.—As above, with thermo-pile.

Compare radiation from bare glass and glass surface covered with gold leaf, on air thermometer or thermo-pile.

Compare temperature of water placed when hot in bright metal and glazed earthenware tea-pots.

A bright and a lamp blackened metal saucepan are filled with cold water and placed at the same distance above a hot metal plate. The temperature of the water is compared after half an hour by the air thermometer. Absorption of radiant heat.

The front of a piece of paper is partly covered with gold leaf, the back is covered with iodide of mercury. A hot iron is held over the paper.

A hot ball is placed midway between two vertical tin plates, one blackened, the other bright towards the ball. Bars of bismuth are soldered to the outside of each plate and connected with the galvanometer.

Show that silvered glass reflects little heat.

Determine dew point by Daniell's hygrometer. Dew.

Test by means of Argand lamp and thermo-pile the thermancy of (1) glass, rock salt, blackened rock salt; (2) water, bisulphide of carbon, blackened (by iodine) bisulphide of carbon, in glass cells; (3) dry air, coal gas, ether vapour, moist air, in a long tube. Thermancy.

Examine the distribution of heat in a solar or electric spectrum formed by a rock salt or bisulphide of carbon prism. Refraction of heat.

Heat-focus of burning glass with sun.

Heat-focus of bisulphide of carbon lens.

The heat of an argand burner with mirror is sent through ice and then focussed.

Electric or solar radiation is analysed by passing through bisulphide of carbon and iodine, it may then be focussed on bulb of air thermometer, &c. Calorescence.

A.—The emergent beam fails to melt ice but fires paper, &c.

Heated ball in focus of one of two parabolic mirrors, gun cotton or blackened bulb of air thermometer in the other. Reflexion of heat.

Ice in focus of one of a pair of parabolic mirrors, air thermometer in the other. Theory of exchanges.

A.—Pyrheliometer, use of.

Heat of friction.

Test heat produced by stropping a razor, sawing, &c. by air thermometer or thermo-pile.

Boil ether, fuse fusible metal by heat of friction, using whirling table.

Hammer a piece of lead and examine its heat.

Drop a leaden ball into a wooden tray from a height of 16 feet.

A.—Experiments with Joule's apparatus.

Mechanical heat.

Air syringe with German tinder or bisulphide of carbon.

Condensation of oxygen by spongy platinum and heating effect.

Spongy platinum over gas, alcohol, camphor, &c.

Moist air in receiver of air pump, show condensation; illuminate by gas jets.

Show expansion of cool condensed air produces cold in air thermometer or thermo-pile.

Compare with heat produced by bellows.

The pendulum illustrates the conversion of potential into kinetic energy.

A.—Illustrations of heat potential in unstable equilibrium in consequence of chemical affinity exhibited by calorimiter, *e.g.*, sulphur, carbon, iron, &c., burnt with nitre under water.

LIGHT.

Sources of light.

Familiar examples of combustion, *e.g.*, wood, wax, paraffine oil, candle, gas, &c. Test for carbonic acid with lime water.

Burn sulphur, phosphorus, magnesium, zinc. Also in oxygen.

Burn antimony in chlorine.

Light of resisting platinum wire.

Comparative luminosity of gases and solids.

Coal gas mixed with air in blow-pipe flame or Bunsen burner. Introduce platinum wire, lime powder, magnesia, silica, &c.

Smoky flame is luminous.

Lime light.

Phosphorescence.

Loaf sugar rubbed in the dark.

Quartz pebbles as above.

Fluorescence.

Powdered fluorspar thrown upon a hot iron plate in the dark.

Phosphate of lime as above.

Insolation.

Sulphides of calcium, barium, and strontium in sealed glass tubes, exposed to light and brought into the dark.

Show by means of model of Earth, Sun, Jupiter, and its satellites the determination of velocity of light by occultation of Jupiter's satellites. Velocity of light.

Construct and explain model of Fitzeau's wheel.

Construct and explain model to show aberration of light.

Obtain small inverted image of a candle flame through a pin hole. Rectilinear motion of light.

Cast the shadow of a broad lath by a flat and edge flame.

Show depth of water when the same quantity is poured into two tin trays of areas 1 : 4. Intensity.

Galvanically incandescent platinum wires in ground glass globes of different diameters.

Wire frame, a long square pyramid with wire frame sections at 1, 2, 4 from the apex.

A square frame is placed half way between a flame and a screen.

A square tube blackened internally with end of ground glass inclined to axis of tube.

Experiment to show that brightness is not diminished by recession.

Experiments with Wheatstone's photometer. Photometry.

Use shadow photometer and show the use of coloured glasses for comparison.

Experiments with Bunsen's photometer, *e.g.*, equal lights at unequal distances, unequal lights at equal distances, &c.

Pierce tin foil in front of a candle or lamp till the images coalesce. Superposition of images.

Show the formation of a round disc of light through an irregular hole.

A parallel beam falls at the foot of a slender white rod fastened perpendicularly to a small silvered plane mirror. Law of reflexion.

A small vertical mirror in the centre of a horizontal graduated semicircle carries an index and receives a horizontal parallel beam, the index and mirror are revolved.

Artificial horizon.

Compare angular motion of reflected beam with that of mirror.

Explain and use Hadley's sextant.

Single and multiple reflexion of small luminous object, the latter from parallel and inclined mirrors. Apparent position of point in mirror.

Use of moveable model of an object, rods from which are hinged upon an edge representing a reflecting surface. The arrangement to show the position of the image in the plane mirror. Apparent relative position of two or more reflected points and formation of images.

Inversion of parti-coloured beam by reflexion from plane mirror.

Experiments with candle flame and mirror to verify the above.

Write with soap on glass plates, view one side directly, the other by reflexion in a mirror, &c.

Reflecting power of surfaces. Compare the brightness of light reflected from silver, silvered glass, plain glass, blackened glass.

Mixed reflected images. Powdered glass. Soap suds. Cast a beam of light upon a plane mirror which throws it on a screen; breathe upon the mirror where the beam impinges, and observe the dark spot on screen.

The shading of an object never reaches its outline.

Increased reflexion by obliquity of incidence.

Reflexion from curved surfaces. Spherical concave mirror. Focus of parallel rays nearly half way between centre of mirror and centre of curvature.

Exact focussing in case of parabolic mirror.

Conjugate mirrors with light in focus of one.

Spherical aberration and caustic; the latter also from cylindrical band.

Positions of focus of point from spherical mirror. Luminous point on axis of spherical mirror—

(1.) Beyond centre of curvature.
(2.) At centre of curvature.
(3.) In principal focus.
(4.) Within principal focus.

Luminous point above or below axis of spherical mirror—

(1.) Beyond centre of curvature.
(2.) Near centre of curvature.
(3.) About principal focus.
(4.) Within principal focus.

Real images. Real image of flame to verify.

Image of illuminated object.

Use of diaphragm to diminish aberration.

Virtual images. Dispersion when luminous point is between mirror and principal focus.

Virtual focus and virtual image with concave mirror.

Convex mirrors. Dispersion of parallel beam.

Dispersion of beam from luminous point on axis of mirror.

Dispersion of beam from luminous point above or below axis.

Image, erect, virtual, diminished.

Oblique reflexion. Focal lines when the beam is incident obliquely.

View a bright coin round the edge of a pail of water.

Transmission and refraction. Displacement of a portion of a straight line when viewed obliquely through a flat slab of glass, or shadow of line focussed on screen and the slab held near the line obliquely.

Displacement of a parallel beam towards base of interposed wedge of glass.

N.B.—*The angle of the wedge should be so acute that little chromatic effect is produced.*

Two equal slabs and wedges of crown and flint glass, displace line and shadow unequally. Inequality of refracting power.

Float ice on warm water and examine the shadow focussed on screen.

Pour hot water through a pipette to the bottom of cold water, focus shadow on screen.

Examine vertical straight line through a cell of water and bisulphide of carbon held obliquely.

Mix water with syrup and alcohol.

Examine shadow of coal gas, also ignited gas jet.

Examine shadow of ether vapour, red-hot poker, and red-hot platinum wire (foreshorten on screen).

Semicircular bath graduated on inside, a window on diameter, and a sliding sine arm, used to prove law of reflexion. Law of refraction.

Disappearance of a glass rod or powdered glass when plunged into a mixture of bisulphide of carbon and ether.

Transparency of waxed paper.

Total reflexion on surface of water in finger-glass of a coin in it. Total reflexion.

Compare superficial and internal reflexions by hypothenuse of right-angled prism.

Inversion without lateral displacement.

Use of water prism with moveable sides, showing total reflexion at one side or at surface of water.

Examine test tube in water, empty and full.

Air on hairy leaves.

Division surface between two liquids totally reflects.

A.—A jet of water curved receives a beam of light and carries it along by internal reflexion.

The use of the camera lucida.

Intersection of two parallel rays passing through two rectangular prisms of unequal sides put base to base; to illustrate the derivation of plano-convex lens. Lenses.

A.—Model of light-house lenses with prisms arranged for camera.

Principal focus for plano-convex lens.

Focus of point on axis of plano-convex. Three examples of distance of point from lens.

Focus of point off the axis of plano-convex. Three examples of distance of point from lens.

Simultaneous foci of two points and formation of images.

Foci and images with double convex lens, as above.

Comparison between concave mirror and convex lens.

Point in axis corresponding with centre of curvature at distance $2f$.

Selected comparative experiments between lens and mirror.

Real image in air viewed from a distance.

Formation of virtual image by convex lens, erect and magnified.

Concave lens.

Dispersion of parallel beam by plano-concave lens, and double concave lens.

Prolongation of focal distance by interposition of plano-concave and double concave lenses.

Virtual image by concave lens.

Spherical aberration.

Variation in focal distance by using different parts of a lens.

Use of diaphragms.

Image of illuminated coin with diaphragm on lens.

Cylindrical lens.

Bright bullet in test tube of water.

The eye.

Construct model of eye by a bolt head or spherical flask of water, a lens and a luminous or illuminated object.

Demonstrate anatomical model of eye.

Image of a luminous body thrown upon a screen (1) behind, (2) within, (3) upon the surface of the eye; by displacement of object and variation of lenses. To illustrate long and short sight and their remedies.

Limits of distinct vision.

A double image of an object seen with one eye close to the object through two pin holes.

Distinct vision within the limits obtained by a pin hole or a lens held close to the eye, which therefore acts as a magnifying glass.

Determine the *punctum cæcum.*

Examine net work of vessels in the eye by a candle in a dark room.

Duration of images and irradiation.

Wheatstone's photometer.

Rotate an illuminated slit above a series of slits.

Apparent superior size of white objects over dark ones.

Platinum wire heated by a galvanic current and viewed through coloured glasses.

Stereoscope and Pseudoscope.

Explain reflecting and refracting stereoscopes and psuedoscope.

Analysis of white light.

Analysis and recomposition of a flat beam of light by glass prisms.

Recomposition of analysed beam by a lens.

Interpose opaque screen or glass wedge at different ends of the spectrum before its recomposition.

Synthesis by rotating discs opaque and transparent.

Cast a spectrum on a plane mirror and thence on to a screen; cause the mirror to vibrate.

Chromatic dispersion of lenses.

Lens of glass containing bisulphide of carbon gives different focal lengths of images for different colours.

Examine the change in colour of the sheath of a conical beam after its rays cross one another.

Dispersion by different media.

A trough prism with divisions receives different liquids, a wide flat beam of light falls upon all. Examine (1) position, (2) length of spectrum.

Examine length of spectra by equal prisms of crown and flint glass.

Show achromatic couple of crown and flint glass prisms.

Show achromatic combination of water and crown glass prisms.

Colour by partial absorption of white light.

Interpose before a source of white light a red glass and a solution of ammonio sulphate of copper in succession and together.

Permanganate of potash in solution is passed along a spectrum; it appears opaque in all colours but its own.

Chromate of potash, as above.

Absorption bands by permanganate of potash solution.

Analyse permanganate coloured beam of light by a narrow prism to show blue, red, and the purple where they overlap.

Colour by reflexion.

Various opaque-coloured objects seen in monochromatic light as alcohol flame in lamp whose wick contains salt. Also in red and green fires.

Subjective colours.

Cast disks of light on screen through solutions of permanganate of potash and ammonio sulphate of copper, and suddenly interpose opaque screen.

Contrast colours.

Throw coloured light over the screen and cast shadows upon it.

Chemical effect of light.

Decompose oxalate of iron under water by light.

Cause equal volumes of hydrogen and chlorine to combine by light.

Decompose iodide of methyl in presence of mercury by light.

A.—Decompose nitrite of amyl by passing light through the glass end of a glass tube containing the rarified vapour of it.

Float blotting paper in succession on brine and a solution of nitrate of silver, and expose a portion of it to the light of the sun or burning magnesium ribbon.

Spectra.

Examination of Fraunhofer's lines in solar spectrum.

A.—Obtain the absorption line of nitrous oxide by interposing a flask of that gas in the spectrum.

A.—Examine continuous spectrum from carbon points of electric lamp.

A.—Obtain the bright bands for silver, copper, zinc, brass, sodium, &c.

A.—Absorb yellow band in sodium spectrum by sodium vapour.

Fluorescence. Examine in violet light uranium glass, quinine solution, turpentine dropped into water, and alcohol; also examine the above in the spectrum.

Undulatory theory. Show colours when oil of turpentine or lemons is dropped upon water.

Show colours of soap bubble.

Cover glycerine-soap bubble with a beaker and observe spot and coloured rings.

Examine the iridescence of lead scum, Nobili's rings, mother-of-pearl, bismuth, ruled gold leaf, Newton's rings. Examine these also in monochromatic light.

Cylinder of liquid to show internal reflexion and dispersion.

Two narrow slits in same plane, one at each end of a tube, to show diffraction.

Lycopodium strewn on glass and a candle flame viewed.

Polarization. Ordinary light can be reflected at every angle.

Diminution and destruction of this power by previous reflexion.

Polarizing angle for glass.

Cast a beam of polarized light upon the apex of a square pyramid of blackened glass.

Compare polarization of reflected ray by black, transparent, and silvered glass.

Gradual and complete polarization by repeated refraction.

Polarization by double refraction. Examine light through tourmaline by tourmaline and by blackened glass; (1) glass used as polarizer, (2) glass used as analyser.

Introduce mica plate between polarizer and analyser.

Show double image by Iceland spar.

Test by tourmaline the plane of polarization in Biot's prism.

Confirm above by reflecting from blackened glass.

Iceland spar cut perpendicularly to optical axis shows single refraction.

A.—Single and double image Iceland spar prism.

Construction and use of Nicol's prism.

Show the effect on polarized light of selenite, quartz, strain, pressure, vibration in glass, heat, &c.

Circular polarization. A.—Use of saccharimeter.

Examine image formed on the ground glass of a camera obscura by a magnifying lens; also examine the real image in the air by a magnifying glass. Selected optical instruments.

Use of Ramsden's eye-piece for viewing cross wires and image together, as used in theodolite, &c.

Huygen's eye-piece for improving the image, increasing the field, and being achromatic.

Erecting eye-piece.

Refracting telescope.

Conversion of reflecting telescope into microscope.

Convex object-glass and concave eye glass; give an erect and magnified image. Opera glass.

Construction of a reflecting telescope with concave mirror and eye-piece.

Application of polarized light to microscope.

FRICTIONAL ELECTRICITY.

Amber rubbed with flannel attracts lath balanced on glass flask, also gold-leaf, bran, feathers, &c. Simple attraction.

Brown paper (hot) rubbed with a clothes brush attracts as above.

Foreign post paper rubbed with bottle india-rubber attracts as above, also clings to wall.

Silk ribbon rubbed with vulcanized india-rubber, as above.

Collodion rubbed with the fingers, as above.

Glass tube rubbed with electric amalgam on silk attracts as above, also paper roller, egg shells, &c.

Sealing wax rubbed with flannel attracts as above.

Stick of sulphur rubbed with flannel attracts as above.

Excited glass attracts every unelectrified body, including bar magnet. Two kinds of electricity.

Excited sulphur and sealing wax attract as above.

Excited glass and excited wax attract one another.

Excited glass repels excited glass.

Excited wax repels excited wax.

> N.B.—*The wax and glass when excited may be placed on little wire stirrups and hung from supports by silk tape.*

Foreign post excited with india-rubber is cut into strips forming a tassel.

The two halves of the silk ribbon excited with vulcanized india-rubber repel one another.

Examine the electricities in the prime conductor and rubber.

Leyden jar.

Elementary jar made by two sheets of tin-foil separated by glass.

Single Leyden jar charged and discharged.

Dissected jar.

Partial discharge of Leyden jar from the glass to the inner coating.

Examine the residual charge, primary, secondary, &c.

A jar cannot be charged unless its outer coating is in connexion with the earth.

Charge a jar with both positive and negative from the same prime conductor.

Faraday's experiment to show the gradual charging of a submarine cable.

Show cascade arrangement.

Measure capacity of jar by unit jar.

Use of pith ball electroscope.

Charge a jar, insulate it, connect interior with earth, and test exterior.

Experiments with jars.

Construct electric battery.

Deflagrate platinum and silver wire.

Explode gunpowder; show use of wet string.

Burst a tube filled with water.

Light ether.

Discharge through eggs, sugar, ivory, lemon, &c.

Discharge through rarefied air, oxygen, hydrogen, and nitrogen.

Pierce paper.

Duration of spark.

Illuminate by a spark a revolving cross or coloured disk.

Velocity.

Model of Wheatstone's revolving mirror and apparatus for velocity.

Atmospheric electricity.

Flame on end of fishing rod connected with the electroscope and isolated.

Examine electricity in steam jet near and some distance from nozzle by conductor and electroscope.

Explain Thomson's electrometer.

Explain and illustrate "return" stroke.

Repel and discharge cotton wool by pointed conductor.

Miscellaneous.

Lichtenberg's figures on electrophorus, varnished glass, ebonite.

Formation of jar by one man standing on insulating stool and grasping another man's hand, a sheet of vulcanized india-rubber intervening.

Test for ozone in brush discharge.

Light gun-cotton by induced spark from flat coil.

Show the effect on astatic needle of friction current from prism conductor.

As above, using $-^{ve}$ electricity.

Change the connexions in both above cases with astatic needle.

Connect secondary coil with astatic needle, and show reversal.

Experiment with tertiary coil.

Tourmaline connected with Thomson's electrometer. Pyroelectricity.

(1.) Heat. (2.) Cool.

VOLTAIC ELECTRICITY.

Deflect astatic needle by selected pairs of metals in salt water, *e.g.*, pin and needle, copper and iron, zinc and lead, &c., and compare with deflection by electricity from prime conductor. Connexion between high and low tension electricities.

Volta's crown of cups with zinc and copper.

Electric potential at the opposite poles, tested (1) with condenser and electroscope, (2) with Thomson's electrometer.

The copper wire connecting the poles attracts filings. Is heated. Condition of the conducting wire.

Deflection of magnetic needle by current:—

(1) above needle in direction (1).
(2) " " " (2).
(3) below " " (1).
(4) " " " (2).

Attraction of filings by coil. Effect of multiplying coils of conducting wire.

Explain and use astatic needle with feeble currents.

Construct simple form of, and explain commutator. Commutator.

Make models of right and left handed helices and reversible conical helix. Helices.

Pass a current across a piece of soft iron:— Magnetism in soft iron by current.

(1) in direction 1 above the iron.
(2) " " 1 below "
(3) " " 2 above "
(4) " " 2 below "

Test the poles of the soft iron.

Magnetise a bar of soft iron in a helix by a current:—

(1) right-handed helix, current direction 1.
(2) " " " " 2.
(3) left " " " 1.
(4) " " " 2.

Large hoop coil; introduce soft iron.

Make horse-shoe electro-magnet, and show simple experiments of attraction.

Polarity of coil.

The polarity of the coil is the same as that of the core.

A suspended helix (solenoid) acts as a bar magnet.

A hoop helix and a tube helix are fastened to a bung and floated on acid water, their terminals are of copper and zinc.

They turn N. and S.

The above are attracted and repelled by the poles of a magnet.

Magnets.

A tin tube sucked into a coil.

Electrical machines.

A.—Froment's machine.

Theory of batteries.

Increased effect (thermal) by increased number of cells.

Show increase of potential by multiplying the cells.

Diminution of effect by lapse of time with single liquid cell.

Deposition of hydrogen on platinum shown by floating the platinum foil.

Polarity of hydrogenized platinum is the same as that of zinc.

Reuter's pile; silver and flannel.

Devices for the elimination of hydrogen :—

(1.) Mechanical; Smee; use of platinized silver.
(2.) Daniell's, substitution of copper for hydrogen.
(3.) Bunsen and Grove; burning of the hydrogen.

Amalgamation of the zinc with mercury.

Electrolysis.

Electrolyse water; examine the proportion and nature of the gases, also their polarity.

Electrolyse salts of silver, copper, lead, &c., using platinum wire electrodes.

Examine the deposition in a drop of solution under the microscope.

Throw focus on screen and shadow of metals during their electrolytic deposition.

Motion of water in direction of current.

In electrolysing water it follows the current.

Force water through a porous cell and show current by platinum poles in the cell and outside.

Electrolytic measurement of current.

Faraday's voltameter.

Guthrie's voltastat.

Magnetic measurement of current.

Tangent galvanometer :—

Explain laws of deflexion for tangent and zinc galvanometers.

General laws of resistance.

Battery of (n) cells and thin platinum wire.

Send a current round a galvanometer and between two platinum spatulae in water :—

(1) increased effect by acidification.
(2) " " approach.
(3) " " deeper immersion.

Repeat as above, using platinum spiral of thin wire instead of galvanometer.

Introduce into circuit from battery around galvanometer different metal wires :—

(1) Variation with substance of wire.
(2) „ „ length „
(3) „ „ sectional area of wire.

Show heating effect of current on compound wire of platinum and silver.

A.—Use of Wheatstone's rheostat.

Galvanometer with single hoop of thick wire to be used. **Ohm's law.**

Vary number of cells with no external resistance.

Vary number of cells with large external resistance.

Vary internal resistance by—

(1) varying size of plates.
(2) „ distance of plates.

Mechanical relations of currents.

1. Currents in same direction attract.
2. Currents in opposite directions repel.
3. Currents crossing one another tend to become parallel.
4. Currents at right angles tend to slide.
5. Ampères' trough and wire to show that one part of a straight current repels the other part.

Induced currents.

1. Setting up current in primary gives reverse in secondary.
2. Cessation of current in primary gives current in same direction in secondary.
3. Approach of primary gives reverse current in secondary.
4. Withdrawal of primary gives same direction of current in secondary.

Ampères' theory of magnetism.

Examine the sliding of a current-bearing wire around a magnet.

(1) Current (1) rotating round north pole.
(2) „ (2) „ „ „ „
(3) „ (1) „ „ south „
(4) „ (2) „ „ „ „

Rotation of a discharge in vacuo around a permanent or electro-magnet.

Examine by galvanometer the current produced through a flat copper coil :—

(1) When placed on north pole of magnet.
(2) „ „ south „ „
(3) When taken off north „ „
(4) „ „ south „ „

Turn the coil over and repeat.

Magnetize a bar of soft iron while in a coil and examine the direction of current. Vary poles.

Magneto-electric machines. Simple magneto-electric machine. Decompose iodide of potassium. Heat platinum wire. Heat between carbon points, &c.

Explain Siemens' armature.

Automatic contact breaker. Explain model of automatic contact breaker.

Ruhmkorff's coil. Model of dissected coil, showing—

- Discharge through vacuum tubes.
- Instantaneous nature of induced current by rotating cross.
- Analyse discharge by a rotating mirror or uranium glass.
- Formation of ozone.
- Induced current in primary or extra current.
- Use of condenser.

Further effect of induced current. Rotation of magnetic needle above a copper disc on the whirling table.

Use of copper plate in compass.

Resistance to motion of conductors in the magnetic field. Copper saw between poles. Copper coin spun between poles. Copper ring dropped between poles. Same broken.

Applications. Working model to exhibit the production of oscillatory motion by an electro-magnet. Conversion of this into a Morse and relay.

Wheatstone's needle telegraph and needle relay.

Electric lamp. Show unequal consumption of poles in air also in vacuo.

Explain differential motion of poles and their regulation by a magnet and spring.

Cake silver on negative pole by the projected carbon.

Wheatstone's bridge. Balance the astatic needle by equal currents.

Interpose unequal resistances produced by variations in length, thickness, temperature, and kind.

Thermo-electricity. Pairs of different metals such as zinc, iron, copper, tin, platinum, silver, bismuth, antimony connected with galvanometer and heated at point of contact.

Cooling produces opposite current.

Passage of current produces heat or cold.

Platinum wire and foil to show that current travels with heat.

Heat one side of tangle in platinum wire.

Thin platinum wire in alcohol thermometer.

Further relation between heat and resistance. Increased heating of platinum wire when a part is cooled.

MAGNETISM.

Show attraction by lodestone on iron filings. **Attraction.**

Directive polarity of lodestone to the earth and to other lodestone.

Steel capable of permanent magnetization, iron not.

Like poles of needles repel, unlike attract. Either pole attracts soft iron. **Polarity.**

Break a hard steel spring magnet into lengths and test the polarity of each. **Poles.**

Determine regions of greatest and least attraction by oscillation of needle.

Determine law of variation of intensity with distance (1) on torsion balance (2) by oscillations.

Compare time of magnetization of steel and of soft iron when in contact with a magnet. **Induction.**

A soft iron bar shifts the pole.

Two permanent magnets placed N to S neutralize and exert little attraction on a soft iron bullet.

Examine the magnetism in a soft iron bar suspended above a permanent magnet.

The greatest possible number of soft iron bullets are suspended from one magnet. Its carrying power is altered by bringing the like or unlike pole of another magnet beneath.

Destroy the magnetism in a small steel spring magnet by red heat. **Relation of heat to magnetism.**

A nearly white hot iron ball is not attracted by a magnet.

Various methods of magnetization, such as single stroke, double stroke, circular stroke, &c. **Magnetization.**

Parallel bar magnets beneath sheet of glass. Scatter iron filings on glass, tap and print with paper moistened with nut-gall and gum-water. **Magnetic curves or lines of force.**

As above, with like poles in conjunction.

As above, with horse-shoe.

As above, with piece of soft iron to be magnetized by induction.

A.—Grove's experiment to show the passage of light amongst oxide of iron suspended in water and surrounded by a coil.

Examples of attraction and induction through wood, glass, brass, &c. **Induction through media.**

Diminution through iron.

Pass a current through a wire wound on a sphere, and compare its magnetism and polarity with that of the earth. **Magnetism of earth.**

Possible cause of earth's magnetism is a series of currents passing from east to west.

A.—Measurement of intensity of earth's magnetism by magnetometer.

Position of earth's poles.

Declination and inclination.

Compare with needle about bar magnet.

Induction by earth.

A soft iron bar parallel to the lines of magnetic force becomes a magnet.

The lower end of a poker when struck with a hammer repels the end of a needle which points to the north.

A current is established in a closed conductor when it is moved, so as to cut the lines of magnetic force.

A bar of soft iron in a coil in the magnetic, meridian, and dip, is connected with a galvanometer and inverted.

Magnetism of iron compounds.

Crystallized sulphate of iron inclosed in a tube and swung between poles of electro-magnet sets axially.

A.—Solution of sulphate of iron in a tube swung between the poles of an electro-magnet sets axially.

A.—Powdered dry white sulphate of iron is scattered on black glazed paper above poles of electro-magnet.

Magnetism of nickel and cobalt.

Test.

Pseudodiamagnetism.

A.—Apparent magnetism due to structure, *e.g.*, short iron wires side by side on wax floating on water. The whole sets equatorially.

A.—A number of iron disks separated by cardboard and forming a bar sets equatorially.

Diamagnetism.

A.—A bar of bismuth swung between poles of electro-magnet sets itself equatorially.

A.—A pellet of bismuth is repelled from either pole.

A.—The flame of a candle is split.

A.—The flame of ether is split.

A.—Oxygen charged with chloride of ammonium vapour assembles round the poles.

A.—Show influence of medium by examining apparent diamagnetism of weak solution of sulphate of iron in a strong one.

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